No. 21. - March 3d - A. M.

Remarks on Animal Respiration. - -

Submitted to the Medical Faculty of the University of

Pennsylvania.

February - 1812. - -

"Nullius addictus jurare in verba magistri."
"Quo me cunque rapit "veritas,"
"deferor hospes."
Horace Lib. 1. Epis. 1.

T h
essen
mate
the s
terms,
the e
by t
inte
retur
ne re
gue
ante
ingu
in of
mal
Nau
to ex
Where
Lun
defin
for n
med
of the
is ai
that
and
red co
in the
Feder

On Animal Respiration.

The action of the heart and lungs is essential to animal existence. The intimate connection that subsists between the sanguiferous and pulmonary systems, is curious and important, and the changes that are effected in the blood by this connection deserve the most minute and careful attention. The blood returned to the heart by the pulmonary veins differs in colour and chemical qualities from that in the pulmonary arteries; and it shall be my object to inquire how this change is effected, or in other words what is the use of animal respiration.- In this inquiry I shall not deem it important minutely to examine the opinions of the earlier Physiologists- as their theories of this function were necessarily vague, indefinite and oftentimes visionary- for no correct hypothesis could be formed without a perfect knowledge of the compound nature of atmospheric air. It is proper however to remark that Lower, Boyle, Verheyen, Borelli and Mayow asserted that the florid red colour of the blood was produced in the lungs, that some change was effected in the air taken into those organs

and
jurn
illus
Phil
of la
made
over
name
But
vague
abut
a re
ing
of
a th
bea
it
The
That
lon
med
wa
ged
a fl
The
That
wit
gas
of ex
The
The
harm
origin

and that some portion of it was con-
sumed in Respiration. Dr Black (a name
illustrious in the annals of Chemical
Philosophy) demonstrated the existence
of Carbonic acid gas in expired air and
made rapid strides towards those dis-
coveries that have immortalized the
names of Priestly and Lavoisier.
But every theory of Respiration was
vague and conjectural until the brilli-
ant discovery of oxygen gas. This gave
a new direction to the labours of inquir-
ing physiologists and upon the basis
of Pneumatic Chemistry they formed
a theory of Respiration at once new,
beautiful and ingenious. By this
it was stated that oxygen gas was
the only essential agent in Respiration
that a portion combined with the car-
bon discharged from the blood and for-
med carbonic acid gas - another portion
was absorbed into the blood and chan-
ged its colour from a dark black to
a florid red, which distinguishes
the arterial from the venous and
that the residual quantity together
with the nitrogen and carbonic acid
gas - was thrown out in every act
of expiration. - Such is the theory of
the supporters of the oxygenation of
the blood - differing however in many
particulars from that which was
originally given to the world. Lavoisier

and
that
the
and
where
carri
taine
by a
form
as it
that
the
to sta
he ad
or rel
whi
exist
obs
habit
insen
is no
and
Dr C
of re
addi
and
to ex
air.
no re
by the
mean
esis d
and

and Crawford, for example, contended that the blood in circulating through the body acquired a quantity of carbon and hydrogen, forming a binary compound which is now known by the name of carburetted hydrogen. This they maintained was discharged in respiration by uniting with the oxygen of the air forming Carbonic acid gas and water. As it is now conceded by physiologists that no hydrogen is discharged from the bloodvessels - it is unnecessary to state the arguments that might be advanced against such an hypothesis or relate the experiments of Bichat which prove that no such gas does or can exist in the bloodvessels - it may be observed, however, that the substances discharged is nothing but the insensible perspiration and of course is not formed by an union of oxygen and hydrogen in the lungs. —

Dr Priestly contended that the colour of venous blood was owing to the addition of his favourite Phlogiston and that the use of Respiration was to expose the blood to dephlogisticated air. I must confess that to my mind no very definite idea is conveyed by this term Phlogiston - but if he meant simply hydrogen - his hypothesis differs not from that of Lavoisier and Crawford and is liable to the

same
prin
tor, a
adm
Prom
does
unna
the
more
Mora
that
ab
gene
no
ever
that,
unde
supp
unco
they
of
brate
conte
air c
this
that
those
repu
and a
from
happ
this p
was a

same objections: if however an unknown principle was supposed to be phlogiston, we certainly are not compelled to admit its existence, until it can be proved — and the supposition that it does exist is wholly gratuitous and unnecessary if we can account for the various phenomena of respiration more philosophically without it. — Modified and corrected by different physiologists, this theory appeared at length, as I have stated it and was generally admitted by the world, for no opinion in Physiology perhaps was ever for a time more popular than that, which maintained that oxygen united with the blood. Some of its supporters began to inquire how this union could be effected and upon this subject considerable difference of opinion existed. Haller, the celebrated physiologist, long since contended, that no absorption of air could take place in the lungs, this he inferred from the mucus that is constantly poured out upon those organs and from the known repulsion that exists between water and air, which prevents the latter from passing through moistened paper, linen or leather. Notwithstanding this opinion the doctrine of absorption was admitted by many, though it

was s
and t
gen la
Char
of colo
vein. f
mark
the vi
of the
of the
arteri
of the
mont
any af
blood
having
an off
that c
unoc
many
certain
tiably
Retard
evide
human
many
intern
coats
this
less
in vi
con
origin
in the

was strenuously opposed by a great
part of the tanner, if we admit that they
are developed in the lungs; still we
find it be unable to account for the change
in the blood in the pulmonary
vein, for in it has been ingenious, it is
marked by the first of these writers,
the air must follow the usual course
of the absorbent vessels in which it was
to be carried not into the pulmonary
arteries or veins, but into the right side
of the heart. — Various experi-
ments were made to ascertain whether
any affinity existed between venous
blood and oxygen gas and Girtanner
having satisfied himself that such
an affinity did exist, he was confident
that it was in this way that oxygen
united with the blood in the pulmo
nary arteries. But Fourcroy has
perhaps shewn that actual contact is even
more necessary for the exertion of
chemical affinity — now it must be
evident that between the air in the
lungs and the blood in the pulmo
nary arteries there must ever be
interposed the membrane lining the lung
walls of the blood vessels and of course
this affinity cannot be exerted, or
less we may suppose it can, through
the intervention of one of its own kind.

Convinced that these two methods
originally stated to shew the manner
in which oxygen unites with the

blood were erroneous unsatisfactory. Some physiologists asserted that there were inorganic pores in the lungs which were constantly open, and through which air might pass freely into the pulmonary sacs. But admitting the existence of such pores (which we unhesitatingly are not bound to do until they have been demonstrated) still the oxygen would not come in contact with the blood, but would only pass into the cellular membrane between the coats of the arteries and the membranes of the lungs, producing emphysematous swelling.* — — — —

It has of late been conceded by some writers, that the three ways in which oxygen is said to unite with the blood are unsatisfactory and by no means capable of explaining the manner in which this union is effected. But they have not been deficient in advancing a new theory or rather a conjecture — which in my opinion is equally untenable with the rest. They maintain that there are a set of absorbent vessels sui generis, that open upon the membranes of the air cells — for the express purpose of conveying oxygen into the pulmonary veins. Without remarking

* Vide Gilman's

that
pile
the s
and
cal
If no
but th
two
supp
gen
gl
man
fect
form
in
blood
can
a fo
usea
tion
wip
has
as con
tinu
affir
not
the. G
to o
cond
wit
have
that

that it is unphilosophical to multiply causes, it may be observed that the supposition is wholly gratuitous and in direct opposition to anatomical fact. — — —

It may not be improper to examine with some degree of attention one or two experiments that have been supposed to demonstrate, that oxygen does unite with the blood, though they by no means point out the manner in which this union is effected. The first of these was performed by Dr Priestly, it was that by which he ascertained that venous blood exposed in a wet bladder to oxygen gas or atmospheric air, assumed a florid red. This experiment has usually been related by the supporters of the oxygenation of the blood with some degree of triumph and has always been considered by them as conclusive in favour of their doctrine. But it does not in reality afford it the least support, we know that in the living animal body the Gall bladder is capable of containing the bile, but how common is it to observe after death all the viscera in the neighbourhood tinged with this thick fluid, that must have escaped through the coats that formerly contained it. The

Ma 10
livan g
lea ff
ex ina
carbo
atio
flat c
recall
was
in of
syste
tin
tomo
the c
mitis
dec th
the
may
in fla
gen.
rom
lea
inf
lea
ing
of in
mad
cons
sur
dain

vadder though impervious in the living body, may no doubt after death, afford a free passage to the entrance of oxygen or the exit of carbon, in consequence of the relaxation that takes place in the fibres that compose it. -- We should also recollect that some considerable time was necessary to effect this change in a few ounces of blood, while in the living system the whole mass of circulating fluid even supposing it to be twenty five pounds undergoes this change in six minutes.* Admitting that these remarks do not destroy or invalidate the effect of the experiment and that it still may be urged with equal force in favour of the theory of the oxygenation of the blood, I would remark that Physiology has been in no way more seriously injured than by reasoning from dead to living matter, by attempting to explain processes that go on in the body by experiments made out of it and by theorizing concerning the living system without remembering that it is endowed with vitality. The other

* See a calculation of Fordyce in his work on Fever.

carbonic acid gas is universally formed
and the oxygen of air is the principle
disengaged. Since the fact is so
no oxygen, Mr Ellis, whose observations
upon this subject are the latest and
by far the most decisive, has been
at pains to ascertain whether oxygen
and hydrogen in their pure state
sufficiently recent to the act the oxy
gen of the air. This only from see
ration of the air

montana infused into a blood vessel of a living animal, a small portion of the venom of the viper, the blood was immediately coagulated and death ensued. But when he mixed it with this fluid as it was flowing from a vessel, no change could be perceived in it and no coagulation took place.

[illegible]

[illegible] experimenting upon living animals [illegible] circulation of the blood. Through the order was explained upon principles merely mechanical, the supposition that the different arteries made small calibre, were calculated with mathematical precision, the different respiratory organs considered to be merely pipes tubes and the animal body merely a hydraulic machine. But physiologists have been obliged to confess that the laws of [illegible] and mathematics are so intimately to the explanation of the functions of living animals and that the vitals

vitality, though imperfectly understood
erates so powerfully that an explanation
animal analogies founded upon the
principles of mechanical philosophy must
be inadequate, they bring out differences

that have not been
sufficiently considered and are sensible
in degree and which has at first sight
the appearance of being conclusive. It has
been maintained that living animals
in a given quantity of air, that the oxygen
contained in the carbonic acid gas must
be equal to the oxygen taken, since it
was concluded that a portion of the
atmospheric oxygen that had been in-
spired had united with the blood,
and it could not be detected in the gas
expired. To this experiment it has
been objected (and I believe by
the Professor of Chemistry in this Uni-
versity) that the respiration of the
animal after the first few first inspira-
tions and expirations must have
become laborious and unnatural
from the increased quantity of car-
bonic acid gas and the diminished
quantity of oxygen gas in the respir-
ing mixture as well endeavour to
establish the laws of the healthy
body by studying the pathology
thereof, it appears as a fruitless
with the changes that take place in the air

the respiration by observing the effects of this process when it is carried on and unnatural.

Hitherto I have only attempted to show that it is impossible for oxygen to unite with the blood and that the experiments that have been adduced to demonstrate the union are so inconclusive and unsatisfactory. A more difficult task remains to be accomplished and that is to account for the change of colour in the blood while passing through the lungs and attempt to explain some of the phenomena of respiration that have been inexplicable upon the former theory. The modern opposition, believing the conditions to be impossibilities that were connected with the theory of the oxygenation of the blood and otherwise the quantity of carbon dioxide or respiration, have maintained that the oxygen not combined with carbon to form the carbonic acid is expired. It will be perceived that this theory differs from the former chiefly in this that the contends that the use of the lungs is to oxygenize the blood while other maintains that it is to venize it. Should it be said that the heat of the body was not sufficient

produce an union between the carbon the blood and the oxygen of the air, rming carbonic acid gas; and might [illegible] saying that this objection can be made by a supporter of the theory the composition of the blood, since it would have equal weight against the theories as the present, for it was this way that they accounted for the presence of carbonic acid gas in expired air. (But this is not the true answer; the ingenuity of the Professor Chemistry has supplied us with one perfectly conclusive and irresistible. We may suppose that the [illegible] [illegible] from the [illegible] [illegible] [illegible] [illegible] [illegible] nitrogen to form ammonia and the which does not require a high [illegible] ature to produce the union, [illegible] [illegible] objection that I have just now at[illegible] [illegible] to obviate [illegible] carbon may [illegible] from [illegible] blood for [illegible] that carbonic acid gas itself [illegible] thrown out from the blood [illegible] [illegible] it is [illegible] that if it [illegible] [illegible] gen contained in the carbonic acid gas expired [illegible] not be [illegible]

as that of the Respiration, as it
is the experiments of Dr. Hartshorne
is inserted hereafter. But this
mark is wholly inapplicable to an
experiment performed by Dr. Hartshorne
twice, with a view to ascertain from
what source the carbonic acid gas
observed to issue "a pregnant
hen under water and transferred
one of the fractures with a jar of pure
azotic gas. The young animal breathed
quietly at intervals for the space
of ten minutes. It then appeared to be
dead and was taken out." Upon exam-
ining the air by lime water, carbonic
acid gas was discovered in it. Dr. Hartshorne
does not inform us, whether the water
employed was distilled water or not
and it is conceived to follow that no
oxygen was used. With the azote, if
it had been equally cautious concern-
ing the water to be used, we should no
doubt have heard of it. We have a
right therefore to assume that the
common water, containing probably
some carbonic acid gas, some atmospheric
air and some oxygen &c. If this were
the case the experiment is completely
invalidated, as the greatest accuracy
is necessary in experiments of this nature
and they are of no value. But in addition
to this I would observe that the fact
remains, that the supposition, viz that
maintained the existence of carbonic
acid gas in the nervous tract "seems to

[illegible] produced carbonic acid, it is not rendered
[illegible] but subsequent experience to suggest
[illegible] may be remembered that in
[illegible] the experiment
[illegible] suggested that the change produced
[illegible] blood in that case might be
[illegible] to the escape of carbonic acid an explana-
[illegible] tion to be performed by Dr Gintrac
[illegible] & think some facts [illegible] to
[illegible] opinion. He exposed a quantity
of venous blood to oxygen gas. Having
[illegible] placed in the air plate
[illegible] he gave a thermometer. The
[illegible] blood soon assumed a fine red colour
[illegible] and the mercury in the thermometer
[illegible] rose a few degrees. Now if the change
[illegible] of colour [illegible] the addi-
tion of oxygen, the temperature
should have been reduced. In the
blood was changed from arterial
to venous and the arterial blood
must be greater capacity for caloric
than venous blood. Of course it could
absorb it from the surrounding bodies
and however was not the fact we
must therefore revert to some other
method of accounting. I believe suppose
that this change was produced
merely by the escape of carbonic acid
and find no difficulty in accounting
for the change of temperature from
the known difference of capacity for

monic while oxygen gas, when combined with carbonic acid gas. (Placing the capacity of water for caloric at 1.000. that of arterial blood is said to be equal to .9300 and that of venous blood to .8928, we must be convinced that this difference of capacity would by no means be sufficient to employ all the caloric liberated by the conversion of carbon and oxygen into carbonic acid gas, unless we recollect that according to the same scale the capacity of oxygen gas is equal to 4.7450, while that of carbonic acid gas is only equal to 1.0454 and of course we may suppose that a quantity of caloric remained sufficient to raise the temperature as has been stated. - The conclusion that Fortanier drew was very different viz. that oxygen unites with the blood that this is so far from being correct, that it is not in the least degree warranted by the premises we have endeavoured to shew. - - -

It may perhaps be asked whence is the carbon derived that is discharged from the pulmonary vessels in respiration, and how is it that so much should be accumulated in venous blood? To this I reply that I by no means wish to be understood that

carbon is imparted to it, and while circulating through the body, as was formerly maintained, nor do we find that the blood acquires any noxious principle in the double course of circulation; but it must be evident that the blood contains a large portion of carbon, both from the nature of our food and the analyses that have been made of that fluid, and it is known, that this principle enters in small proportion into animal matter. now in the extreme effects even the animal fluids and solids are formed, those parts of the blood that enter into their formation are separated from the carbon and other constituent of that fluid and in this consists the conversion of arterial into venous blood and the use of Respiration is to discharge the carbon and render the blood again fit for the purposes of the animal economy.

From this view of the subject, imperfect as it is, it must be evident that the doctrine of the decarbonization of the blood, so far from innovating on the established records of the general principles of nature in all physiological and is amply sufficient to explain the changes produced in the blood while passing through the lungs.

[illegible] fortunately for us we can adduce
the strongest proof of its correctness
in a fact that has escaped [illegible]
[illegible] - but can be adopted only [illegible]
[illegible] to direct experiment. Upon
[illegible] our apparatus seems to answer
[illegible] and supplied the best
[illegible] not in the least doubt
[illegible] a view to ascertain the relation
[illegible] the consumption of oxygen and
the formation of carbonic acid gas. The
[illegible] instituted a lot of experi-
ments which satisfactorily prove
that there is no excess of oxygen
consumed above that which is necessa-
ry to the formation of the quantity
of carbonic acid gas which is produced
[illegible] but that the
[illegible] is equivalent to the other. The
accuracy of these experiments none
can doubt, and [illegible] of
great respectability have admitted
that they [illegible] the theory
of the oxygenation of the blood by
[illegible] whose opinion is certainly
deserving attention, when [illegible]
of the theory of [illegible] which supposes
that carbon and hydrogen were
united to the blood while circulating

though the lungs and that carbon may
unite. That oxygen was absorbed or
fixed in a state of loose combination in
venous blood remarks that, "an effec-
tive to such hypotheses, not less important,
that the changes which respiration
are not analogous to the chemical
changes, which take place in the
animal economy, and that they are
not sufficiently connected with the
purposes which the blood serves in
its circulation."

Analogy will furnish some support
to the theory of the decarbonization of
the blood, for by carefully attending
to the changes that vegetables pro-
duce in the air, there can be no doubt
but that the same processes go on in
them as in animals. It may be said
that analogical facts or reasoning con-
ter apposite, should have sufficient
weight. True. They are here means
advanced as direct proof, but as a
species of collateral evidence they
are of importance as they aid that
which is more positive. — It appears
in a variety of experiments, that
oxygen gas is essential to every period
of vegetation. During germination it
must be supplied, it is absorbed
the seeds crack, and it is given

carbonic acid gas is formed
and the quantity of air in the vessel is not
increased. Since the seed absorbs no
oxygen, these experiments
upon this subject are the strongest and
by far the most decisive has shown
that growing vegetables require oxygen
and that carbonic acid gas is formed
sufficient to account for all the oxy-
gen consumed. It is only from such
a view of the subject that we can
offer any satisfactory explanation
of several phenomena connected with
vegetation. Thus are, for example, some
plants that will continue to grow at
a temperature below 32° of Fahrenheit's
thermometer or in other words they
will continue to perform all the func-
tions of a living vegetable. if one of
these is surrounded by snow, it will
~~continues~~ melt that portion that
is nearest to it. This fact is familia
to every one. The explanation of it
is perfectly simple. The living plant
discharges carbon which unites with
the oxygen of the air forming carbonic
acid gas. and as this gas has a less
capacity for caloric than oxygen a
quantity of the caloric fluid is extri
cated, sufficient to produce the

ted. – If equal quantities of water exposed in similar vessels, to a temperature sufficiently low partially to congeal the fluid and if in the one be place branches of living vegetable and in the other the same quantity of dead wood, – crystals of ice will be seen in the latter while no congelation will take place in the other. This experiment was performed by Mr J Hunter, and has been repeated with similar results, by the Professor of Materia Medica in this University. It may be explained precisely in the same way as the last. – I shall notice only one other analogical fact. In the large end of the egg, there is a quantity of air; experiments have shown, that this is oxygen gas. In applying the tongue to this portion of the egg – so long as it is sound & alive, a degree of warmth will be imparted to it. – This can only be owing to the gradual conversion of oxygen in this portion of the egg and the carbon thrown out from the substance of it, into carbonic acid gas, and the warmth is owing to the different capacities of the two gases for caloric.

After this process of decarbonization goes
not only in the ova of animals, but in
germination and growth of vegetables,
it explains not only animal respira-
tion but several phenomena connected
with it inexplicable by the other
hypothesis and if a hypothesis it is
supported by direct experiment.
Inclusive and accurate, why should
we for a moment withold our assent
from it? or why should we not rather
endeavour to point out its superior-
ity over the theory of the oxygenation
of the blood, as it is more simple,
intelligible and consistent with
the laws of the healthy body? -

By considering a few facts connected
with respiration and attempting
to explain them, I shall conclude these
remarks. According to the experiments
of Lagrange and Lavoisier it appeared
that less oxygen was consumed in a
high temperature than a low one. The
explanation of this fact is by no
means difficult. By the experiments
mentioned by Mr. Ellis, it was ascer-
tained that the skin discharges
carbon, and not carbonic acid gas as
was been supposed; in a hig-tempera-
ture, this discharge would be increased
in consequence of the increase of

respiration and of course the skin vicarious
perform in part the vicarious office
of the lungs, assisting them to discharge
the superfluous quantity of carbon from the
blood. — May we not suppose that
the peculiar colour of the skin indicates
disease upon a partial application of
it to the internal organs from
the that the vicarious office of the
skin is suspended by the obstruction
of pores, that a quantity of carbon
thrown upon the lungs greater
than they are able to discharge and
consequently that the blood is more par-
tially freed from that principle
which gives the dark black colour
to that fluid in the pulmonary
vessels? — — — In all chronic affe-
ctions of the lungs, which is high ly
deleterious, hence the Professors of the
institutes of Medicine have recom-
mended that during the winter
season pulmonary patients should
be kept in a temperature uniformly
mild. The high and respectable author-
ity from which this advice comes
would leave me no reason to doubt of
its excellence, even if I were unable to
see the reason or object of it. But this is
not the case. and it may be seen

be corrected in the following way. In
some persons the lungs are debilitated
and diseased — even the performance
of their usual office is attended with
pain and by increasing their duty (by
a forced) the body (world) we only add
to the complaint. By suffering the
skin to perform its vicarious office
we prevent the danger that would
arise from crowding the lungs with
blood charged with carbon which
they would be unable to throw off
and death would no doubt in very
many instances be the consequence. —

From a moment's at-
tention to the subject it must be
evident, that many other physiolog-
ical and pathological inferences
of more importance might be drawn
from this theory — but as many think
it far from being perfectly established,
I shall proceed no farther. —
I am aware that in offering objections
to the theory of the oxygenation
of the blood, I am opposing the
opinions of a very large majority
of the physiologists of the
present day. But the prevailing
opinion is by no means always the correct

-i it is not very many years
since the mechanical theory of di-
gestion was very popular and if man-
kind had feared to attack it from
the number of its supporters, one
would have had at the present-
day an hypothesis which maintained
that bones were digested by the mas-
ticatory power of the stomach. Though
it was unable to explain how many
of the substances passed through
that organ without being acted
upon. I am far from intending that
the recovery of the oxygenation of the
blood is as probable and rational
as the old one. Some stock on the
other hand I think that it has much
improbability and discovers no small
degree of rashness and impatient.
It is hence rather wonderful that
it should have been so generally
adopted, after its first promulgation
it served to add to the importance
of oxygen gas which had just been dis-
covered and which it was so natural
to mankind were disposed to think
was the sine qua non, without which
vascular life could not proceed.
This theory made it the great stimulus
that vivified life and maintained

that as it circulated through the body with the blood it stimulated every part of the system into action. Dr Fletcher and some others advocated the opinion that oxygen was the excitant and supported their opinions with a number of experiments. In fine, there is been no station assigned for oxygen, as it related to the animal body; but it may be questioned whether the introduction of chemistry into physiological science will be productive of those immensely important consequences which its supporters have always supposed.

The examination of the subject that has been made at the present time is deficient no doubt in many very important points; if it were proper to apologize. The author would observe that it was written in great haste, in a space of time unexpectedly short and amid a variety of avocations that could not be dispensed with. Certain he is,

that
any
old
fa
his o
from
home
duc
ome
was
infl
Pat
perfe
This
rega

at if he has not brought forward
y important objections to the
ol. theory or any strong argument
favorable of the next it is from
is own want of powers and not
from the barrenness of the subject.
Some points might have been
elucidated by experiments and
ome positions confirmed - and it
as originally intended to have
erformed these - but those causes
that produced the numerous im-
erfections in the other parts of
this thesis, operated equally with
regard to this. — — —

Finis.